

ART. XXIV.—*On the Separation and Analysis of Minerals in the Dacite of Mount Dandenong, Victoria.*

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INTRODUCTION.

As no information was available regarding the composition of the minerals of variable composition in the dacites of Victoria, it was suggested by Professor Skeats that this work should be undertaken; and it was hoped that thereby some light would be thrown on the relation existing between these minerals in the normal dacite, and in the gneissic rocks which he has discovered in contact with the dacite in the Dandenong ranges.

Very little in the way of determining the composition of Victorian rock-forming minerals seems to have been done, and the only record I can find of an analysis of a ferro-magnesian mica is one done by the late Dr. Howitt and published in his paper on the "Rocks of Noyang."¹

The objects of this research work can be tabled under three heads:—

- i. To separate the minerals Biotite, Hypersthene and Ilmenite from the rock.
- ii. To analyse them and make a bulk analysis of the rock.
- iii. To see what light chemical evidence would throw on the probable formation of secondary minerals in the rock.

THE DACITE.

The sample used in this work was obtained from a quarry alongside the railway line, a little on the Ferntree Gully side of Upwey station, on the Gembrook line, and is believed to be a

¹ Proc. Roy. Soc. Victoria, vol. xx., p. 24.

representative sample of the normal dacite in that area. It is a dark-grey, and very hard compact porphyritic rock. In the hand specimen phenocrysts of a dark-brown mica, biotite, in well-formed hexagonal flakes, can be seen, also phenocrysts of feldspar, but further than that little else can be observed megascopically. Under the microscope in thin sections one can see abundant phenocrysts of plagioclase, generally with regular outlines, and very often zoned, dark-brown biotite, pale-green hypersthene, quartz very occasionally, and an opaque mineral which may be either magnetite or ilmenite, all set in a fine-grained crystalline groundmass of quartz, feldspar and biotite.

Of the minerals in the rock the plagioclase feldspars can be determined optically by the Michel-Lévy method, and so definite compositions assigned to them; but it is necessary to separate and chemically analyse the minerals biotite, hypersthene, and the opaque mineral in order to learn their compositions.

The proportions of the phenocrysts and groundmass are about equal, and as the average diameter of the former is only .1 mm., it was seen that the separation of them in sufficient quantity and in a pure enough state for a chemical analysis would be a matter of some difficulty.

METHODS OF SEPARATION ADOPTED.

The minerals to be separated are all iron-bearing, so that the electro-magnet suggested itself as a means to the desired end; accordingly one as described by T. Crook,¹ of the Imperial Institute, London, was used.

By a combination of the electro-magnet with the use of heavy liquids and various shaking devices, and finally picking with a wet brush underneath the microscope, the minerals were obtained pure enough for chemical analysis.

The electro-magnet consists of a cylindrical piece of soft iron, 1 inch in diameter, bent into U shape and having vertical limbs about 6 in. long and 3 in. apart. Each limb is provided with a bobbin on which is wound seven layers of insulated wire (16 gauge), each layer having about 40 turns. Two pole pieces,

¹ "The Use of the Electro-Magnet in Petrography," by T. Crook, A.R.C.Sc.I., F.G.S. Science Progress, No. 5, July, 1907.

consisting of soft iron about $1\frac{1}{4}$ in. wide and $\frac{1}{3}$ in. thick, are slotted so as to move over screw-clamps which fit into the ends of the limbs. By this means the pole-pieces can be adjusted in any desired position.

The electro-magnet is connected with the ordinary lighting circuit of 200 volts alternating current, the latter being converted into direct current by means of a Noden-valve arranged by Mr. Grayson, of the Geological Department. Suitable resistances were obtained by means of ordinary incandescent lamps, 6 of which, of varying capacities, were used, giving an amperage ranging from $\frac{1}{2}$ amp. to 3 amps., the voltmeter indicating 10 volts for the latter value.

PREPARATION OF THE SAMPLE.

The fresh representative sample was first crushed into pieces about the size of peas by means of a small jaw-crusher, this material was then crushed up in a steel mortar, so that it would pass through a sieve with openings about .2 mm. square (20 sieve), but remain on a 40 sieve with apertures about .1 mm. sq. This size was found most convenient for the separation of the larger flakes of mica. After the mica had been removed from this it was further crushed so as to be caught on a 60-sieve with apertures .06 mm. sq.

The larger size was more convenient for the separation of the mica, while the smaller size was required for the hypersthene.

SEPARATION OF THE MINERALS.

It was found that the separation of the mica from the hypersthene by means of a magnet could not be done very satisfactorily, but in transferring the powders in cardboard boxes it was noticed that the flaky biotite had a tendency to stick to the bottom of the box, while the other rounded grains rolled off easily. This peculiarity of the mica was utilised, and proved especially valuable, for while the magnet served to separate the mica and hypersthene from the other minerals in the rock, the gentle shaking in cardboard boxes with one end cut away, served to separate the mica from the hypersthene.

Mica.—By means of a bar-magnet all the steel splinters off the mortar, and grains of opaque material that would come out were removed; then the powder was subjected to the electro-magnet with the pole-pieces 4 mm. apart, and all the material which would come out while 3 amperes were run through the magnet was removed.

This magnetic material was made up of free grains of biotite, hypersthene, and composite grains of either or both these minerals with felspar and quartz, or with the magnetic opaque material. By gentle shaking of the cardboard boxes held at a slight angle and with one end cut away, the biotite was separated from the other material, small lots being treated at a time and given several shakings.

By means of Sonstadt's heavy liquid of Spec. Gr. about 3, used with a Sollas Separator, the free biotite was separated from most of the other material, only a few composite grains of hypersthene and mica coming down also. The material was then washed and dried, and the composite grains picked out with a fine wet brush underneath the low power of the microscope. This was a very laborious process, but only in this way could quite pure material suitable for analysis be obtained.

Hypersthene.—The powder whose grains were about .1 mm. in diameter was used for obtaining this mineral. With a voltage of 10 (3 amperes) and pole-pieces 4 mm. apart, the magnetic material, which separated readily, was removed by the electro-magnet. On breaking the circuit a certain amount of material still adhered to the pole-pieces, and was made up of small steel splinters from the mortar, fragments of ilmenite and leucoxene, and in some cases pieces of quartz or felspar containing inclusions of the opaque mineral. The magnetic material separated as above contained grains of hypersthene, biotite, ilmenite, quartz and felspar containing magnetic inclusions, and a fair amount of composite grains of the above minerals.

Under the microscope it was noticed that hypersthene grains very often enclosed large patches of the opaque material.

By means of card-shaking the biotite was removed almost completely. The remaining material was then subjected to a voltage of 3 with pole-pieces 4 mm. apart, the material removed

in this way was seen to be largely the opaque mineral, hypersthene containing large inclusions of the former mineral, leucoxene, and quartz and felspar containing magnetic inclusions. The voltage was then increased to 10 (3 amps.), and all the material was picked up with the exception of a few quartz and felspar grains, and several small flakes of biotite.

By means of Sonstadt's solution of Spec. Gr. 3, used with a Sollas Separator, a practically pure hypersthene product was obtained, the quartz and felspar being removed with the exception of a few composite grains, which were easily picked out with a wet brush.

An examination of the hypersthene under the microscope detected opaque material in nearly every grain, so with a view to getting rid of as much as possible of this it was ground finer in an agate mortar, and subjected to 4 volts, with pole-pieces 4 mm. apart. A good deal of magnetic opaque material was removed thus. After picking over with a wet brush under the microscope, this mineral was ready for chemical analysis.

Ilmenite.—An attempt was made to separate this from the rock powder by the magnet, but as it is present to the extent of only one per cent., is largely included in other minerals, and is in such small grains it would have been a lengthy process to separate enough for a chemical analysis. The separation has been done by nature, however, and some of the material as it occurs in the stream sands in the dacite area was obtained. It is remarkably fresh, and although the sample was not obtained from exactly the same locality as the rock sample, it is believed that its composition is similar to that contained in the material used for separation and analysis.

ANALYSES OF ROCK AND MINERALS.

Besides analyses of the three minerals of variable composition in the rock, one was made of the rock itself. All the analyses were made in duplicate with the exception of that of the ilmenite. Agreement between the duplicates was satisfactory, and the analyses appended below are those of one of the duplicates and not the mean of two determinations.

Formula.	Mol. Weight.	Mineral.	Norm. Group.	%.	Group.	%.
SiO ₂	.3985 × 60	Quartz	24.0	Q	24.0	} Sal 82.3
K ₂ O . Al ₂ O ₃ . 6SiO ₂	.029 × 556	Orthoclase	16.1	} F	56.0	
Na ₂ O . Al ₂ O ₃ . 6SiO ₂	.038 × 524	Albite	19.9			
CaO . Al ₂ O ₃ . 2SiO ₂	.072 × 278	Anorthite	20.0			
Al ₂ O ₃	.023 × 102	Corundum	2.3	C	2.3	} Fem 16.8
MgO . SiO ₂	.062 × 100	} Hypersthene	12.6	P	12.6	
FeO . SiO ₂	.0475 × 132					
FeO . Fe ₂ O ₃	.005 × 232	Magnetite	1.2	} M	3.6	
FeO . TiO ₂	.016 × 152	Ilmenite	2.4			
FeS ₂	.0025 × 120	Pyrite	0.3	} A	0.6	
3Ca ₃ P ₂ O ₈ + CaF ₂	.001 × 310	Apatite	0.3			

Class	=	$\frac{\text{Sal}}{\text{Fem}} = \frac{82.3}{16.8} < 7/1 > 5/3 = \text{Class II.}$	Dosalane
Order	=	$\frac{\text{Q} + \text{L}}{\text{F}} = \frac{24.0}{56.0} < 3/5 > 1/7 = \text{Order IV.}$	Quardofelic Austrare
Rang	=	$\frac{\text{K}_2\text{O} + \text{Na}_2\text{O}}{\text{CaO}} = \frac{67}{72} < 5/3 > 3/5 = \text{Rang III.}$	Alkali-calcic Tonalase
Sub-rang	=	$\frac{\text{K}_2\text{O}}{\text{Na}_2\text{O}} = \frac{29}{38} < 5/3 > 3/5 = \text{Sub-rang III.}$	Sodi-potassic Harzose

CALCULATION OF FORMULÆ OF THE MINERALS.

	BIOTITE.			HYPERSTHENE.			ILMENITE.		
	Per cent.	Mol. Prop.	Ratio.	Per cent.	Mol. Prop.	Ratio.	Per cent.	Mol. Prop.	Ratio
SiO ₂	39.86	664	} 6.4	55.22	920	} 16	67.28	841	} 1.8
TiO ₂	7.95	99							
Al ₂ O ₃	11.13	109	} 1	4.44	43	} 1	31.92	443	} 1
Fe ₂ O ₃	1.39	9			2.30				
FeO	18.10	251	} 4.2	22.33	310	} 12	0.80	20	} 1
MgO	9.88	246			14.27				
CaO				0.24	4				
MnO	0.58	8		0.25	3				
Na ₂ O	0.35	5							
K ₂ O	6.73	71	} 2.1	0.76	7	} 1			
H ₂ O	3.20	178			0.06		3		

Formula 2R₂O.4RO.R₂O₃.6RO₂ 3RO.4RO₂ RO.2RO₂

Biotite - 2 (KH)₂O . 4 (FeMg)O . Al₂O₃ . 6 (SiTi)O₂
 Hypersthene - 3 (FeMg)O . 4SiO₂
 Ilmenite - (FeMg)O . 2TiO₂

COMMENTS ON THE ANALYSES.

Dacite.—The composition of this dacite is seen to be quite normal, except that perhaps the TiO_2 percentage is a little higher than usual in rocks of this type. A comparison of this analysis with one of a dacite¹ from near Braemar House, Mount Macedon, shows that the two are almost identical. In composition this rock much resembles a quartz-mica-diorite from Ensay,² Omeo, analysed by the late Dr. Howitt, and it is interesting to note that all three fall into the same sub-rang when classified according to the American classification—viz.:—

Class II.—Dosalane.

Order IV.—Quardofelic, Austrare.

Rang III.—Alkali-calcic, Tonalase.

Subrang III.—Sodipotassic, Harzose.

The Ensay rock, however, nearly passes into subrang iv., while both the dacites are well in subrang iii.

Biotite.—The SiO_2 , FeO and TiO_2 percentages are high, while the alumina and alkali percentages are low. This mineral in thin sections, under the microscope shows inclusions of ilmenite, thus the TiO_2 and FeO percentages are too high, while all the other constituents are correspondingly low. The biotite itself is believed to be titaniferous, so that it is difficult to know how much TiO_2 to assign to the biotite and how much to the enclosed ilmenite; consequently no deduction was made from the analysis for these two oxides, with the result that the RO_2 and RO ratios are a little too high.

The formula for this mineral, according to the analysis, is $2R_2O.4RO.R_2O_3.6RO_2$. So that it is not an orthosilicate like the typical biotites.

Hypersthene.—In this analysis the FeO percentage is slightly higher than usual, while the MgO percentage is considerably lower than in a normal hypersthene, with the result that the formula for this mineral is $3RO.4RO_2$.

1 Annual Report of the Secretary for Mines Victoria, 1907, p. 61.

2 Proc. Roy. Soc. Victoria, vol. xxii., p. 99.

Ilmenite.—The TiO_2 is extremely high, while Fe_2O_3 is absent, and MgO is present to a small extent, the FeO percentage being about normal.

The mineral is strongly magnetic, which is rather curious, as it is generally stated that only when you get a combination with magnetite does the mineral exhibit strong magnetic properties. The formula for this mineral is $RO \cdot 2RO_2$.

DETERMINATION OF P_2O_5 IN THE ANALYSES.

In determining this constituent by the magnesium-pyrophosphate method, according to Washington,¹ the values obtained were obviously high, consequently the method was abandoned, and that of Finkener² by direct determination of the ammonium phospho-molybdate, adopted with satisfactory results. Dr. H. I. Jensen³ has encountered a similar difficulty and overcome it in this manner.

CALCULATION OF THE MODE OF THE ROCK.

The volume percentage of each mineral in the rock was estimated by Rosiwal's⁴ method. The application of this method to the rock presented considerable difficulty on account of the fine-grained groundmass, which is made up of quartz, felspar and biotite, the average diameter of these grains being only .01 mm., and that of the phenocrysts .1 mm.

In the groundmass the biotite was easily distinguished by its colour, while the slight difference in refractive index between the quartz and felspar was utilised in discriminating between these two minerals.

Sections were cut from the same sample of the rock as the analyses were made from, and as a result of traverses in several directions. Out of a total volume of 6389 the volumes of the different minerals were as shown in the accompanying table. The percentage volumes were then calculated and multiplied

1 H. S. Washington, "Chemical Analysis of Rocks."

2 Treadwell, "Analytical Chemistry," vol. ii., p. 347.

3 Proc. Linn. Soc., N.S.W., 1907, vol. xxxii., pp. 908, et seq.

4 Verhandl. d. k. k. Geol. Reichsanst., 1898, pp. 143, et seq. "The Quantitative Classification of Igneous Rocks," p. 204, 1903. J. P. Iddings, Journal of Geology, vol. xii. (1904), p. 225.

by the specific gravities, giving the gravimetric proportions of the different minerals from which the percentages by weight were obtained.

A number of determinations of the felspar phenocrysts by the Michel-Lévy method resulted in the majority of them giving extinction angles for $Ab_1 An_1$ but an occasional one for Ab_2, An_3 . The specific gravities of hypersthene and ilmenite were determined by means of a small specific gravity bottle, while that of the biotite was determined by floating flakes in any position in a solution of Methylene Iodide in benzine, and then determining the specific gravity of the solution by a Westphal balance.

The specific gravity of the felspar phenocrysts was determined from a knowledge of their composition and reference to tables.

CALCULATION OF MODE.

PHENO-CRYSTS	MINERAL	VOLUME.	PERCENTAGE VOLUME.	SPECIFIC GRAVITY.	GRAVIMETRIC PROPORTIONS.	MINERAL PERCENTAGE.
PHENO-CRYSTS	Plagioclase ($Ab_1 An_1$) -	1629	25.50	2.68	68.34	24.13
	Hypersthene - - -	656	10.27	3.36	34.50	12.17
	Biotite - - - - -	628	9.83	3.16	31.06	10.96
	Quartz - - - - -	84	1.31	2.65	3.47	1.22
	Ilmenite ¹ - - - -	40	0.62	4.86	3.07	1.08
	Felspar ($Ab_3 An_3$) -	1553	24.31	2.675	65.03	22.95
GROUND-MASS	Quartz - - - - -	1389	21.74	2.65	57.61	20.34
	Biotite - - - - -	410	6.42	3.16	20.27	7.15
		6389	100.00		283.35	100.00

	QUARTZ.		FELSPAR.					Hyp.	Bi.	Il.	Composition from Mode.	Composition as Analysed.
	Pheno-crysts.	Ground-mass.	Pheno-crysts.	Groundmass.								
				Or.	Ab	An.						
SiO ₂ -	1.22	20.34	13.42	5.28	5.00	3.23	6.72	7.25			62.46	63.27
Al ₂ O ₃ -			6.83	1.51	1.42	2.75	0.55	1.97			15.03	16.50
Fe ₂ O ₃ -							0.28	0.25			0.53	0.68
FeO -							2.72	3.29	0.35		6.36	5.10
MgO -							1.73	1.80	0.01		3.54	2.48
CaO -			2.51			1.52	0.03				4.06	4.18
Na ₂ O -			1.37		0.86			0.06			2.29	2.36
K ₂ O -				1.38			0.09	1.22			2.69	2.68
H ₂ O + -							0.01	0.58			0.59	0.52
H ₂ O - -							0.01	0.08			0.09	0.09
TiO ₂ -								1.50	0.72		2.22	1.30
MnO -							0.03	0.11			0.14	0.03
Total -	1.22	20.34	24.13	8.17	7.28	7.50	12.17	18.11	1.08	100.00	99.50 ²	

1 As Phenocrysts and in the Hypersthene.

2 Including 0.15 per cent. P₂O₅ and 0.16 per cent. S(FeS₂).

From this table it will be seen how close the microscopically estimated chemical composition is to that determined by chemical analysis.

The silica has been slightly under-estimated, but as about 50 per cent. of the rock is a fine-grained groundmass with grains averaging only .01 mm. in diameter, their discrimination by means of the difference of refractive index was a matter of some difficulty.

The discrepancies between the Al_2O_3 percentages and those of the FeO and MgO suggest that the analysis of the porphyritic biotite recorded above is not representative of all the biotite in the rock.

Under the microscope, besides the large phenocrysts of biotite one sees developed granular masses of what appears to be a secondary biotite around the ilmenite, and it has been suggested by Professor Skeats that this secondary mica arises as a result of interaction between the ilmenite and feldspar of the groundmass under certain conditions, and also between the hypersthene and groundmass less commonly. If that is the case it cannot be assumed that all the biotite throughout the rock is of uniform composition, but that at least we have two different kinds of biotite.

With biotite arising from ilmenite and the groundmass, one would expect a low MgO percentage, as the ilmenite is very low in this constituent, while the groundmass feldspar has none; if this percentage were low the Al_2O_3 value would probably be high, so that if one knew what composition to assign to this secondary biotite it is highly probable that the Al_2O_3 , FeO and MgO percentages would be more comparable.

The alkalis and lime are remarkably close, so that the feldspars appear to have been correctly determined.

The ferric-iron and water are close, while discrepancies arise between the TiO_2 and MnO values. On the whole, however, the analyses are as close as one could expect to get them, considering the structure of the rock and its fine-grained groundmass, and if one could estimate the composition of the secondary biotite it is thought that the comparison would be still closer.

Another point showing the closeness of the two analyses is that the position of the rock, according to the American classi-

fication, is the same, whether calculated from the norm or mode.

SUMMARY.

The minerals hypersthene, biotite, and ilmenite occurring in the dacite have been separated and analysed. The method of separation was a combination of the use of an electro-magnet with heavy liquids and various shaking devices, and gave satisfactory results.

These minerals and also the rock were then chemically analysed, and formulae obtained for the minerals.

The norm of the rock was calculated from the chemical analysis, the mode of the rock by the application of Rosiwal's method, and from this the chemical composition of the rock was estimated microscopically. A close agreement was found to exist between the compositions obtained chemically and microscopically.

CONCLUSIONS.

The groundmass felspar appears to be a mixture of orthoclase and a plagioclase ($Ab_9 An_1$), and is more acid than the felspar phenocrysts, as one would expect.

In the groundmass are present all the constituents which, together with either ilmenite or hypersthene are necessary to form biotite, thus supporting the microscopical evidence of the secondary origin of some of the biotite.

It would also appear that the secondary biotite derived from the ilmenite and groundmass contains less magnesia and more alumina than the primary biotite.

In conclusion, I am much indebted to Professor E. W. Skeats for the kindly interest he has taken in this work, and for the great assistance he has rendered me whenever in difficulties, also to Mr. H. J. Grayson, whose ingenuity on many occasions simplified matters considerably.